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Broadening a nature of science conceptualization: Using school biology textbooks to differentiate the family resemblance approach

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Abstract

Previous research about the presence of nature of science (NOS) within science textbooks has been found to be lacking in sufficient coverage. However, given the shift in how scholars conceive of NOS, the shortcomings may not be present in the textbooks but rather in the NOS frameworks used to analyze textbooks. Whereas traditional NOS has taken a more generalized approach to describing scientific practices, the family resemblance approach (FRA) to NOS recognizes variability in the scientific disciplines as reported by practicing scientists as well as philosophers and historians of science. Instead of suggesting that NOS can be applied equally in educational settings to all scientific disciplines, the FRA accounts for cognitive-epistemic and social-instructional conceptual elements which more authentically represent science. This study sought to evaluate textbooks using this more recent NOS conceptualization to explore the potential range of NOS aspects. Using the proposed FRA categories, seven German biology textbooks were analyzed with qualitative content analysis. The combination of cognitive-epistemic and social-institutional systems of science revealed that the FRA was a suitable mechanism for analyzing textbooks' coverage of NOS. Notably, FRA's distinct attention to modeling (absent from the discipline-general NOS approach) revealed its presence in textbooks that would have gone unnoticed. Another finding was that the textbooks tended to emphasize the cognitive-epistemic systems over the social-institutional. Finally, this study found that even with a broader set of categories and subcategories to the FRA, the application to analyze was reliable.

KEYWORDS
biology, curriculum, family resemblance approach, nature of science, qualitative content analysis, textbooks

1 | INTRODUCTION

Driver et al. (1996) argue *why* students should learn about nature of science (NOS). They outline that an understanding of NOS is necessary if students are “to make sense of the science and manage the technological objects and processes they encounter in everyday life” (p. 16), “to make sense of socio-scientific issues and participate in the decision-making process” (p. 18), “to appreciate science as a major element of contemporary culture” (p. 19), to “develop awareness of [...] the norms of the scientific community, embodying moral commitments which are of general value” (p. 19), and to learn science content more successfully (Driver et al., 1996). These arguments have been criticized as being “primarily intuitive with little empirical support” (Lederman & Lederman, 2014; p. 600), however, they feature prominently across a large body of science education literature (e.g., Erduran & Kaya, 2018; Kaya, Erduran, Aksoz, et al., 2018; Leden et al., 2020; Lederman, 2019). Thus, the arguments seem to be normatively defined objectives emphasized by researchers and educators.

For students, an understanding of how knowledge is gained and applied is highly relevant for making informed decisions in life. Among others, textbooks play an important part in shaping such understandings (Mullis et al., 2012), as evidenced by their pervasive role on all levels of the curriculum. According to the Tripartite Curriculum Model, textbooks are defined as potentially implemented curriculum, which mediate between the intended curriculum (e.g., standards documents), the implemented curriculum (e.g., classes), and the achieved curriculum (e.g., students' knowledge; Valverde et al., 2002; see Remillard & Heck, 2014).

In standards documents and other official documents for the science education of students in different countries (e.g., England: Department for Education, 2015; Germany: KMK, 2020; USA: NGSS Lead States, 2013), the objectives to achieve scientific literacy include the formation of an adequate NOS understanding. However, a review of NOS studies (Lederman & Lederman, 2014) indicates that students' understanding (representing the achieved curriculum) is insufficient: “Without any targeted instructional interventions, students do not possess the currently desired understandings of NOS” (Lederman & Lederman, 2014; p. 603). Likewise, empirical studies reveal that textbooks inadequately represent NOS content (e.g., Abd-El-Khalick et al., 2008, 2017). At the same time, the consensus view on NOS (see Kampourakis, 2016), upon which most of the studies build on, has been described as undifferentiated and philosophically inadequate (e.g., Erduran, 2014). An alternative NOS conceptualization, theoretically based on the family resemblance approach (FRA) has been used for educational purposes to describe a holistic approach that considers scientific disciplines as members of a family, sharing similarities in some respects and differences in others (Erduran & Dagher, 2014a; Irzik & Nola, 2011, 2014; van Dijk, 2011). Currently, few studies employ FRA to NOS as a theoretical background for providing results of curriculum and textbook analyses. These studies "point to the methodological utility of FRA" (Erduran et al., 2019; p. 325). However, it is not systematically researched yet which FRA aspects apply to all sciences and which only to individual disciplines such as biology or chemistry: "Future studies are needed to explore the range of NOS components embedded in individual science topics and disciplines using the fine-grained analysis afforded by the FRA" (Erduran et al., 2019; p. 325). The conceptualization so far has mainly been used by providing 11 categories of NOS (Erduran & Dagher, 2014a; Kaya, Erduran, Aksoz, et al., 2018). For empirical investigations and analyses, a fine-grained analysis could be provided by refining the initial category system (Erduran & Dagher, 2014a), which means to further differentiate the categories of the FRA. The overall project is in response to these research gaps related to the FRA to NOS, with this article focusing on the development of a category system including more distinctive FRA categories.

In the following, we will first explain the significance and usefulness of school textbooks. Typically, science education studies examine the quality of textbook content, for example in terms of NOS representation. In contrast, existing curriculum models reveal a stronger potential of textbooks in science education research than simply evaluating school textbooks as "good" or "bad."

2 | THEORETICAL BACKGROUND

2.1 | Curriculum models and textbooks

In the science and mathematics education literature, different curriculum models are described. Their common task is to depict educational opportunities systematically (Remillard & Heck, 2014). Educational opportunities include "the configuration of social, political and pedagogical conditions to provide pupils [*sic*] chances to acquire knowledge, to develop skills and to form attitudes concerning school subjects" (Valverde et al., 2002; p. 6). It is assumed that a curriculum exists in various forms and at several levels in the education system. The actors concerned with this system interpret the curriculum in various ways (Remillard & Heck, 2014).

Following the Tripartite Curriculum Model, the intended curriculum requires certain potential learning experiences and sets goals, which should be achieved ("Intentions, Aims and Goals"; Valverde et al., 2002; p. 5). These are often formulated at a national level, for example in standards documents. The implemented curriculum contains strategies, practices, and activities, which are meant to be realized in class. The attained curriculum refers to the ideas, constructs, and schemes students possess after educational processes (Valverde et al., 2002; see Schmidt et al., 1996). Other curriculum models are more differentiated, including further elements such as students' interests and their selfefficacy (Remillard & Heck, 2014). Instructional materials, especially textbooks, are referred to as potentially implemented curricula because they mediate between the intended and the implemented curriculum. Compared to standards documents (intended curriculum) they are more closely linked to the actual teaching-learning activities (implemented curriculum). Textbooks are used in a variety of ways for the design of educational opportunities. The specific impact of textbooks on teaching processes varies (Remillard & Heck, 2014; Schmidt et al., 1996; Valverde et al., 2002). Curriculum requirements such as standards usually do not show in which way the content requirements should be implemented in classrooms. Textbooks serve as a link between normative settings and classes (Valverde et al., 2002). Furthermore, they are considered a significant component of learning environments (Thompson et al., 2013).

Remillard and Heck (2014) refer to the official and operational curriculum which largely correspond to the intended and implemented curriculum, respectively. Textbooks and other instructional materials have a flexible and influential role in specifying the official curriculum, they serve as a resource for teachers when planning classes, and as a tool for students. "Instructional materials are one type of resource that has been found to significantly shape the nature of classroom interactions" (Remillard & Heck, 2014; p. 713). The importance of textbooks is also reflected in the Trends in the International Mathematics and Science Study (TIMSS) of 2011, in which it was found that 74% of science teachers use textbooks as the basis for their classes (Mullis et al., 2012). It has to be noted that the development of digital textbooks and, more generally, digital media might by now be influencing this trend and it is not clear yet to what extent this may impact classroom learning (see Ivić, 2019). It can be assumed, however, that printed textbooks will serve as a basis for the development of digital textbooks and that there will be correlations between the content of printed and digital textbooks with both forms being seen as potentially implemented curricula.

2.2 | Discipline-general conceptualization of NOS

Based on Kampourakis (2016), a distinction can be made between NOS aspects that are common to all disciplines (discipline-general) and those, which are unique to the specific discipline (discipline-specific). A structured framework for the teaching of discipline-general NOS content to students (i.e., the NOS consensus view; Lederman & Lederman, 2014) typically address seven aspects (see Kampourakis, 2016), which are also considered in many NOS related studies (e.g., Abd-El-Khalick et al., 2017; Capps & Crawford, 2013): (1) Scientific knowledge is tentative, (2) empirically based, (3) subjective, (4) culturally embedded, and (5) includes human imagination and creative components. Moreover, the differentiation between (6) observation and interpretation as well as between (7) theories and laws are considered to be important.

Abd-El-Khalick et al. (2008, 2017) investigated to what extent NOS aspects are (adequately) represented in 48 US-American biology, chemistry, and physics school textbooks. For this purpose, Abd-El-Khalick et al. (2008) developed a category system and a scoring rubric, based upon the seven aspects of the discipline-general NOS conceptualization. Among other things, they consider the extent to which the identified text passages represent NOS content implicitly or explicitly. In several studies in which the category system and the scoring rubric were applied, it was found that NOS aspects are only present in small amounts in the analyzed textbooks. Furthermore, the presented NOS aspects were mostly regarded as inadequate concerning their accuracy (Abd-El-Khalick et al., 2017; Aydın & Tortumlu, 2015; Wei et al., 2013).

2.3 | Criticism of the discipline-general NOS conceptualization

It has been criticized that the aspects of the discipline-general NOS conceptualization contain specifications with certain, in part no longer adequate scientific perspectives (Erduran, 2014; Matthews, 2012; Reinisch, 2018). Erduran (2014) contrasts the five tenets of logical positivism with the NOS consensus view to recognize that, among other things, the notion of neutrality of scientific claims as devoid of bias and individual subjective prejudice had led to the dichotomy of objectivity and subjectivity, and the separation of scientific fact from subjective interpretation. It is worthy to note that earlier depictions of objectivity was [*sic*] grounded on individually centered accounts (e.g., Bacon) where no significance was placed on interactions among scientists. Subjectivity was based on individual psychological bias and prejudice that interfered with objectivity of science (Erduran, 2014; pp. 96-97).

Erduran (2014) then refers to more contemporary philosophical accounts which "have reshaped the way that we think about objectivity and subjectivity whereby the social articulation and evaluation of scientific claims are paramount to the establishment of objectivity in science" (p. 97).

The focus on common features of all natural sciences and the (more or less) neglect of specific characteristics of individual scientific disciplines (see Köchy, 2008) within science education are called into question (Dagher & Erduran, 2014; Gilbert & Justi, 2016; Reinisch, 2018; Schizas et al., 2016). Schizas et al. (2016) compared ontological, methodological, and epistemological features of Newtonian physics and evolutionary biology (Neo-Darwinism). They found that the scientific practices differ significantly and that the answer to the question "What is science?" very much depends on the field of science. A homogeneous, discipline-general NOS conceptualization does not consider this diversity, which is why Schizas et al. (2016) call for the implementation of a heterogeneous approach of NOS for teaching-learning processes. By doing this, NOS perspectives, which mostly stem from the field of physics (Dagher & Erduran, 2014; see Köchy, 2008), could be extended to biology- and chemistry-specific aspects (Erduran, 2014; Vesterinen et al., 2013). For example, within the field of biology, philosophers question if there even exists anything that could be called a law (Reutlinger et al., 2019; Rosenberg, 2008). Another example relates to the performance of experiments and the interpretation of corresponding results. In chemistry and physics, errors in the identification of causal relationships are usually traced back to faulty measuring equipment or inaccuracies in the planning and execution of an experiment. Errors in biology also go back to the variability of living beings (Bässler, 1991).

In empirical studies, the discipline-general NOS conceptualization is often used as the theoretical basis (e.g., Abd-El-Khalick et al., 2017; Capps & Crawford, 2013), leading to responses from study participants which do not give insight into a differentiated understanding about science and its processes (Schizas et al., 2016). Neumann and Kremer (2013) point out that it has not yet been empirically clarified to what extent a cross-disciplinary construct or multiple discipline-specific constructs must be assumed in relation to NOS.

Based on a survey of scientists (biologists, chemists, geospatial and space scientists, physicists), Schwartz and Lederman (2008) found that there are differences in the understanding of NOS among the scientists depending on their scientific discipline. However, the authors conclude that there is no overarching pattern to determine the relevance of discipline differences within primary and secondary education. Other studies focus on only one NOS aspect such as models and modeling ("meta-modeling knowledge" as part of NOS; see Gilbert & Justi, 2016). Krell et al. (2015) show that students have a less elaborate understanding of biological models than of chemical or physical models. This is interpreted as a consequence of different learning opportunities in each school subject. On another note, Tsai (2006) found that students consider biological knowledge more tentative than physical knowledge. These results were confirmed for preservice teachers (Topcu, 2013). In addition, chemical knowledge is considered more certain than biological knowledge. The surveyed preservice teachers argued that biology is more open to new knowledge or developments (Topcu, 2013).

In sum, there has been a consensus for some time about which NOS aspects should be integrated into the science curriculum (Lederman & Lederman, 2014). However, in recent years, more and more voices are being raised that this consensus is not adequate (e.g., Erduran, 2014; Matthews, 2012; Schizas et al., 2016).

Consequently, the above-mentioned textbook studies lack what is demanded in the presented criticism. These studies do not differentiate between discipline-general and discipline-specific aspects (Vesterinen et al., 2013). In the following, a NOS conceptualization is shown that considers this criticism.

2.4 | A holistic conceptualization of NOS: The FRA

Irzik and Nola (2011, 2014) propose the application of FRA to NOS as a conceptual basis in science education (van Dijk, 2011). The approach stems from a philosophical perspective (Wittgenstein, 1958) and has been developed further for philosophy of science (Irzik & Nola, 2011, 2014). Irzik and Nola (2011) describe the idea of the FRA as follows:

> There are many items called 'science', ranging from archeology to zoology. […] So what do these many sciences have in common? The idea of family resemblance will tell us that this is a wrong question to ask. What we need to do is investigate the ways in which each of the sciences are similar or dissimilar, thereby building up from scratch polythetic sets of characteristics for each individual science. (p. 595)

In the FRA, the individual scientific disciplines are considered as members of a family, who share similarities in some respects. For example, the method of observation is relevant for all sciences (discipline-general). However, observing cannot be considered as a unique feature of science because it is also used in nonscientific endeavors. Only specific features of the observation (e.g., targeted observation by means of certain measuring instruments) show the scientific character. In addition, within the FRA features are described that apply only to some of the disciplines (discipline-specific). For example, in most sciences the experimental approach is considered essential to generate knowledge. However, in astronomy experiments are not possible. Instead, observations and the peculiarities of observation relevant to astronomy play an important role (Irzik & Nola, 2011, 2014).

Erduran and Dagher (2014a) furthered the development of the FRA in the field of science education by drawing on the work of Irzik and Nola (2011, 2014). They also highlight the need of further investigations for science education research purposes:

> The effectiveness of the FRA model is yet to be investigated. The development of the FRA for educational use at this current stage is primarily conceptual and must be followed up with additional translational work that involves curriculum revision followed by empirical studies to determine optimal design of effective science curriculum and instruction. (Erduran & Dagher, 2014a; p. 35; see Kampourakis, 2016)

In contrast to the discipline-general NOS conceptualization, the FRA contains categories (Table 1) that can be filled by constantly expanding discipline-general and discipline-specific contents without specifying certain philosophical directions (e.g., logical positivism; Kaya & Erduran, 2016; van Dijk, 2011). Thus, the FRA "enables us to show which aspects of science might support different views of what science is without the need to commit ourselves to any view" (van Dijk, 2011, p. 1095).

The FRA includes categories, which are important in science philosophy, and which have similarities with the aspects of the discipline-general NOS conceptualization, the demands of official curricula (McComas & Olson, 2002), and experts' conceptions (e.g., Osborne et al., 2003). It is emphasized that the FRA can be significant in terms of the question as to *what* NOS content students should fundamentally understand to make informed choices as citizens in a science and technology-driven society (Heering & Kremer, 2018).

2.5 | Curriculum analysis using the FRA

As outlined above, textbooks and other instructional material are considered potentially implemented curriculum while standards, curriculum guidelines, and similar documents are intended curriculum (Valverde et al., 2002). FRA-related analyses of the latter (e.g., standards) are available from England and the USA (Erduran & Dagher, 2014a), Ireland (Erduran & Dagher, 2014b; Kelly & Erduran, 2019), and Turkey (Kaya & Erduran, 2016). In addition, standards documents from the United States, Korea, and Taiwan were analyzed and compared regarding three categories of the FRA (Park et al., 2020). It was shown that the FRA is suitable to identify how various NOS aspects are elaborated on in curriculum documents (Erduran & Dagher, 2014a). The analysis of two Turkish curricula revealed that the four categories of the cognitive-epistemic system of science (Table 1) are included in all analyzed curricula, but that there is limited reference to the categories of the social-institutional system (especially regarding professional activities, political power structures, and financial systems; Kaya & Erduran, 2016). Furthermore, studies (Erduran & Dagher, 2014b; Kaya & Erduran, 2016) provide suggestions for extending the analyzed curricula in line with the promotion of a NOS understanding, in which not only individual categories are separately highlighted, but also presented in a holistic and interconnected manner. The presentation of the individual categories identified in the curricula remains at the level of "natural sciences." No discipline-specific features for biology, chemistry, or physics are named. This might be traced back to the fact that the official curricula are mostly related to science subjects in general.

TABLE 1 Categories of the family resemblance approach (FRA) to nature of science (McDonald, 2017; pp. 104–105; adapted from Erduran and Dagher, 2014a)

FRA-category	Description
Cognitive-epistemic system of science	
Aims and values	The scientific enterprise is underpinned by adherence to a set of aims and values that guide scientific practices. These may include accuracy, objectivity, consistency, skepticism, rationality, simplicity, empirical adequacy, prediction, testability, novelty, fruitfulness, commitment to logic, viability, and explanatory power.
Scientific practices	The scientific enterprise encompasses a wide range of cognitive, epistemic, and discursive practices. Scientific practices such as observation, classification, and experimentation utilize a variety of methods to gather observational, historical, or experimental data. Cognitive practices such as explaining, modeling, and predicting are closely linked to discursive practices involving argumentation and reasoning.
Methods and methodological rules	Scientists engage in disciplined inquiry by utilizing a variety of investigative and analytical methods to generate reliable evidence and construct theories, laws, and models in a given science discipline, which are guided by particular methodological rules. Scientific methods are revisionary in nature, with different methods producing different forms of evidence, leading to clearer understandings and more coherent explanations of scientific phenomena.
Scientific knowledge	Theories, laws, and models are interrelated products of the scientific enterprise that generate and/or validate scientific knowledge, and provide logical and consistent explanations to develop scientific understanding. Scientific knowledge is holistic and relational, and theories, laws, and models are conceptualized as a coherent network, not as discrete and disconnected fragments of knowledge.
Social-institutional system of science	
Professional activities	Scientists engage in a number of professional activities to enable them to communicate their research, including conference attendance and presentation, writing manuscripts for peer-reviewed journals, reviewing papers, developing grant proposals, and securing funding.
Scientific ethos	Scientists are expected to abide by a set of norms and ethical standards both within their own work, and during their interactions with colleagues and scientists from other institutions. These may include respect for research subjects, respect for the environment, freedom, carefulness, openness, respect for intellectual property, confidentiality, responsible publication, responsible mentoring, respect for colleagues, social responsibility, nondiscrimination, legality, animal care, human subjects protection, and so on.
Social certification and dissemination	By presenting their work at conferences, and writing manuscripts for peer-reviewed journals, scientists' work is reviewed and critically evaluated by their peers. This form of social quality control aids in the validation of new scientific knowledge by the broader scientific community.
Social values of science	The scientific enterprise embodies various social values including social utility, respecting the environment, freedom, decentralizing power, honesty, addressing human needs, and equality of intellectual authority.
Social organizations and interactions	Science is socially organized in various institutions including universities and research centers. The nature of social interactions among members of a

(Continues)

TABLE 1 (Continued)

FRA-category	Description
	research team working on different projects is governed by an organizational hierarchy. In a wider organizational context, the institute of science has been linked to industry and the defense force.
Political power structures	The scientific enterprise operates within a political environment that imposes its own values and interests. (The findings of science do not benefit everyone equally, and they) are not always beneficial for (all) individuals, groups, communities, or cultures (in the same way).
Economics of science[a]	The scientific enterprise is mediated by economic factors and refers to science/scientists in the industry, the commodification and commercialization of science, and the funding of scientists so that they can carry out their work. Thus, funding organizations have an influence on the types of scientific research conducted.

[a]The category and part of its description is taken from Kaya, Erduran, Birdthistle, et al. (2018); originally, the category was named "financial systems."

There are a few textbook analyses based on the FRA. In the same way as the analysis of official curricula, discipline-specific NOS features regarding biology, chemistry, or physics are not identified in these studies. BouJaoude et al. (2017) examined three Lebanese school textbooks, one each in biology, chemistry, and physics of the 9th grade, by using a qualitative content analysis. While there was no NOS content in the Physics textbook, 6 of the 11 categories could be identified at least once in one of the other two textbooks. All text passages except for one referred superficially or implicitly to NOS content. In particular, the categories of the social-institutional system of science are neglected. The authors conclude that the analyzed textbooks do not address NOS content in a systematic or adequate way. They also emphasize the benefits of the FRA as a basis for textbook analysis to identify a wide range of NOS content. In addition, the authors detect missing NOS content, assess the quality of NOS content presentation, and use analysis results to improve or add NOS content in textbooks (BouJaoude et al., 2017).

Park et al. (2019) examined chapters referring to the general relativity theory in five physics textbooks for Grades 11 and 12 by a qualitative content analysis. They found that "textbooks" references to NOS are concentrated on aspects related to scientific knowledge, scientific practice, scientific methods, and professional activities of scientists, whereas the characteristics of science as a social-institutional system are underrepresented" (p. 1055). The authors differentiated some of the FRA categories into subcategories. For example, they found five subcategories for the cognitive-epistemic category "scientific knowledge": (a) Theories allow us to interpret the same phenomenon in a new way, (b) Physics knowledge is subject to change and grows over time, (c) Theories have predictive power, (d) Models are used to explain phenomena, and (e) Some theories are more general than other theories. For three categories, no evidence was found in the analyzed material. Park et al. (2019) limit their results to the context of the relativity theory. Thus, the list of subcategories is only valid for one specific topic in the field of physics. The authors suggest that their implications for teaching science could be extended to NOS aspects in other school science subjects.

McDonald (2017) applied qualitative content analysis to analyze chapters on genetics in four Australian 10th-grade biology textbooks. For each of the FRA's 11 categories, she was able to find at least implicit evidence. However, within the analysis, a differentiation into discipline-specific (biology: genetics) and discipline-general NOS content was not made. The author highlights the usefulness of the FRA as a basis for analysis but emphasizes the exploratory nature of her study and the requirement to conduct further investigations in relation to other disciplines of the natural sciences (e.g., chemistry) and subdisciplines of biology (e.g., evolution). "Findings from research conducted in these areas will [...] contribute to scholarship utilizing both domain-general and domain-specific approaches to NOS" (McDonald, 2017; p. 114).

In sum, textbook studies which use the discipline-general NOS conceptualization (e.g., Abd-El-Khalick et al., 2017) emphasize the lack of NOS-content in school science textbooks. Comparatively, studies in which the FRA was used as underlying conceptualization seem to reveal more NOS-content (e.g., McDonald, 2017) with the authors highlighting the need for further studies. It can be assumed that the FRA offers a much broader theoretical background for analysis as more NOS aspects are included.

2.6 | Development and evaluation of the structure of the FRA

The FRA and its structure ("conceptual elements"; Erduran & Dagher, 2016; p. 161; e.g., differentiation into the cognitive-epistemic and the social-institutional system of science) were primarily developed based on theoretical work (e.g., Irzik & Nola, 2011, 2014). The authors emphasize that there are "examples of applications to curriculum and textbook analysis as well as infusion in preservice and inservice teacher education contexts [which] illustrate the empirical power of the expanded FRA in informing and transforming science education" (Erduran & Dagher, 2016; p. 161).

However, already a rough consideration of the FRA categories (Table 1) leads to the assumption that there is a lack of discriminatory power among the 11 categories. For example, both the categories "professional activities" and "social certification and dissemination" include the activity of scientists writing manuscripts for peer-reviewed journals and the activity of evaluating research (Table 1). Although these aspects are seen from different angles, depending on the category, it is questionable if the categories are useful for empirical research purposes or if they should be revised to create more distinct categories.

> The definition [of a category] should enable you and others to recognize instances of the category in your data and to distinguish between one category and other, similar categories. Now imagine what will happen if the definitions you have come up with do not measure up to this standard: most likely, units of analysis will sometimes be coded as instances of one category, sometimes as instances of another category – in other words, the categories will be used inconsistently. In this way, low consistency will point you to flaws in your coding frame; it will show you that those categories that were used inconsistently need to be improved. This is the first way in which reliability can be put to use in [qualitative content analysis]: as a pointer to flaws in your coding frame. (Schreier, 2012; p. 168; see Schreier, 2014)

Further, Schreier et al. (2019) report on the challenge that sometimes one unit of coding is assigned to more than one category, which can be encountered by modifying the coding frame or the unit of coding on the one hand or to identify theoretical over-differentiations on the other hand. The latter leads to the reduction of a category system (Schreier et al., 2019; Spendrin, 2019). However, Spendrin (2019) reports on theoretically expectable overlaps, which must not lead to questioning justifications of single categories. A decisive factor for this is an explainable connection between the contents of the codings, which are distinct in their matter. Hence, such theoretical overlaps appear to be multilayered unities of meaning, which unite different NOS categories in an interconnected way.

Gearing towards the provision of subcategories provided by Park et al. (2019; see above), the construction and evaluation of a more fine-grained category system with distinct categories enables us to provide further structure of the FRA and hence, to explore how NOS aspects are "interactive with porous boundaries" (Erduran & Dagher, 2014a; p. 143).

3 | AIM AND RESEARCH QUESTIONS

The study is part of a larger project, which aims to identify and differentiate a NOS conceptualization to describe both discipline-general and biology-specific NOS categories. Thus, the project contributes to the extension of current NOS knowledge for the field of science education (Erduran & Dagher, 2014a; Heering & Kremer, 2018;

Vesterinen et al., 2013). It aims at a systematic, empirical analysis of the FRA as provided by Erduran and Dagher (2014a; see van Dijk, 2011) and, thus, its target is an extension of the discipline-general NOS conceptualization in terms of biology-specific NOS characteristics. The present study, as first part of the project, aims at the empirical examination of the FRA (Erduran & Dagher, 2014a) and the identification of distinct subcategories of the 11 FRA categories (Table 1). The subcategories should serve in further studies as a basis to differentiate between discipline-general and biology-specific aspects of NOS.

Textbook studies in which the FRA was used as an underlying conceptualization show promising results in detecting NOS content in school science textbooks (e.g., McDonald, 2017). Considering that textbook chapters such as the introduction usually offer the most NOS content (Abd-El-Khalick et al., 2017), we assume that the analysis of more than one selected chapter in biology textbooks should reveal NOS content on a broader scale. A cursory glance at German biology textbooks from the secondary level supports this assumption (see below for further explanation on this procedure). Thus, we assume that biology school textbooks might show a concrete and detailed way in which NOS aspects are presented when using the FRA as a theoretical background. Taking this into consideration, the first research question (RQ 1) of this study is as follows: *Which subcategories of the 11 FRA categories can be identified by analyzing the potentially implemented biology curriculum (i.e., textbooks)?*

To construct subcategories which can be evaluated as distinct, methodical considerations by Schreier (2012, 2014) and Schreier et al. (2019) are considered and will also lead this study: *To what extent is it possible to construct theoretically distinct and applicable subcategories for the FRA?* By answering this second research question (RQ 2), it is aimed to evaluate the usability of the FRA (Erduran & Dagher, 2014a) as a category system to describe the structure of NOS contents in a sufficient and adequate way (Schreier, 2012, 2014; Schreier et al., 2019; Spendrin, 2019).

4 | METHODS

4.1 | Sample

The mother language of the researchers conducting this study, and who did the textbook analysis, is German. Thus, for a detailed text analysis, it was fitting for the researchers to choose textbooks written in German.

Abd-El-Khalick et al. (2008, 2017) report that different editions of the same textbooks hardly differ over the course of several decades in the presentation of NOS aspects. They also state that textbook authors have a much greater influence on the integration and design of NOS than the publishers of textbooks (author-effect; Aydın & Tortumlu, 2015; Wei et al., 2013). DiGiuseppe (2014) reports on both an author-effect and a publisher-effect. Since it was an aim to identify the greatest possible variance of NOS content for the differentiation of the FRA category system (maximizing differences; Kelle & Kluge, 2010), textbooks from different publishers (publisher effect) and from different author groups (author effect) were selected for the analysis.

Considering an extension of the project regarding further levels of the curriculum (e.g., attained curriculum), textbooks are selected which are mostly used in schools and are expected to have an influence on students' understanding. Therefore, books from three of the largest school textbook publishers in Germany were selected (Cornelsen Bildungsgruppe [C], Ernst Klett Verlag [K], Westermann Verlagsgruppe [W]; Buchreport Redaktion, 2017). The publishers were contacted to find out about their most popular school biology textbooks. Even if no specific circulation levels were mentioned, each publisher named one or two books that met this criterion. Furthermore, in a questionnaire survey, 60 biology teachers from all over Germany, who also give seminars for trainee teachers, each named a school biology textbook which is used in their school. As an outcome, seven textbooks were determined for the analysis:

For lower secondary level (Grades 7–10; SI):

- Textbook C-SI: Biosphäre. Band 7–9 Gymnasium Nordrhein-Westfalen (*Biosphere. Edition for classes 7–9 of secondary school in Nordrhein-Westfalen;* Leienbach, 2016; ISBN: 978-3- 06-4200071-5)
- Textbook K-SI: Natura 7–10. Biologie G9-Ausgabe (*Natura 7–10. Biology edition for 9 years of secondary school;* Bickel et al., 2020; ISBN: 978-3-12-049541-3)
- Textbook W-SI: Bioskop. SI. Ausgabe für Rheinland-Pfalz (*Bioscope. Lower secondary level. Edition for Rheinland-Pfalz*; Hausfeld & Schulenberg, 2016; ISBN: 978-3-14-150690-7)

For higher secondary level (Grades 11–12 or 13; SII):

- Textbook C-SII: Biologie Oberstufe SII. Gesamtband (*Biology senior level. Complete volume*; Weber, 2016; ISBN: 978-3-06-010345- 4)
- Textbook K-SII: Natura Biologie Oberstufe (*Natura Biology senior level*; Bickel et al., 2016; ISBN: 978-3-12-049131-6)
- Textbook W-SII-B: Biologie heute. SII. Erweiterte Ausgabe (*Biology today. Higher secondary level. Extended edition*; Braun et al., 2012; ISBN: 978-3-507-19800-5)
- Textbook W-SII-L: LINDER Biologie SII. Gesamtband. Lehrbuch für die Oberstufe (*LINDER biology for higher secondary level. Complete volume. Textbook for the senior level*; Bayrhuber et al., 2019; ISBN: 978-3-507-11280- 3)[1]

Due to the high volume of data often found in textbook studies, partial analyses are typically performed (Abd-El-Khalick et al., 2017; Khine, 2013). Therefore, selected chapters of the textbooks were examined. Based on research findings reported in the literature (cited below), four chapters were particularly suitable for the analysis of NOS content:

- *Introduction* (e.g., “Methods,” “What is biology?”; Abd-El-Khalick et al., 2017; Chaisri & Thathong, 2014; Chiappetta & Fillman, 2007),
- *Cell biology* (Abd-El-Khalick et al., 2017; Chiappetta & Fillman, 2007; Wei et al., 2013),
- *Genetics* (Abd-El-Khalick et al., 2017; Chiappetta & Fillman, 2007; Erduran & Dagher, 2014a; McDonald, 2017), and
- *Evolution* (Abd-El-Khalick et al., 2017; Chaisri & Thathong, 2014; Chiappetta & Fillman, 2007; Erduran & Dagher, 2014a; Wei et al., 2013).

All elements of the four chapters from the textbooks (e.g., text elements, information boxes, instructions, figures, tables, tasks) were analyzed. Elements intended to provoke students' activities, such as instructions and tasks, were analyzed by additionally considering the level of expectations formulated in the teachers' manuals (further context analysis; Schreier, 2014).

4.2 | Data processing and analysis: Development of the category system

Before the systematic selection of textbooks and chapters, we skimmed through several school textbooks from different secondary levels. We made particular note to ensure the introductory chapters were fully read, with the content of the FRA in mind, by the first author of this paper to receive an impression of possible NOS content within the textbooks. This first examination confirmed the findings of McDonalds (2017) and Park et al. (2019) who emphasize the usefulness of the FRA as an underlying framework. Also, it was found that textbooks that are used in higher secondary level (Grades 11–12 or 13; SII) contain more NOS content than those for lower secondary level (Grades 7–10; SI). Hence, the four selected chapters of two of the school textbooks for senior grades (textbook C-SII, textbook W-SII-L, 2014[1]) were analyzed in the first step of the systematic analysis procedure. The selected chapters were scanned and converted into PDF files which included text recognition (Adobe Acrobat 9 Pro software) to make them accessible in the MAXQDA analysis software (VERBI Software, 2019).

The analysis of the data was done according to the structuring qualitative content analysis, which includes a deductive-inductive approach (Mayring, 2014; Schreier, 2014; Stamann et al., 2016): According to the theoretical basis (Erduran & Dagher, 2014a), 11 categories (Table 1) were already established before the analysis (deductive approach; Schreier, 2014). Coding units were defined for the coding procedure (Kuckartz, 2018; Mayring, 2014). Since textbooks already consist of certain elements (e.g., text elements, information boxes, figures), structures for the definition of coding units were already available (e.g., a figure including the headline). A coding guideline with coding rules (Neuendorf, 2017) based on the FRA categories was established by the first author. The coding guideline includes literature sources for the theoretical and methodical approaches as background knowledge, a definition for the coding units, a description of each of the 11 categories, and examples for the categories taken from Erduran and Dagher (2014a). Two coders (preservice biology teachers working on their master thesis) were trained to code the material. In addition to an initial discussion of the category system and the coding guideline, the two coders selected 12 coding units (called "codings" in MAXQDA). Two codings were selected, which could be clearly assigned to one of the categories by the two coders. Eight codings could not be clearly assigned and two codings could clearly be rated as irrelevant by them (i.e., no NOS content included). On this basis, the coders and the first author discussed the codings until the coding procedure was understood and plausible to the two coders. As a next step, while each coder coded 10% of the selected material from one of the two books, the first author coded the same 10% of both books. Subsequently, the codings were compared and discussed until consensus was reached (Schreier, 2014). The category system and the coding guideline were modified accordingly. The two coders coded the rest of the material individually (one for each book).

With the help of the Code Relation Browser provided by MAXQDA overlaps of the codings were made visible (VERBI Software, 2019). This function of the software was used to detect overlaps between categories. Theoretically expected overlaps which are not due to empirical distinctiveness, but show confluence of different content-related matters, were identified in line with Spendrin (2019). For each main category, all codings were collectively examined and inductively differentiated into subcategories while qualitatively considering the prominent overlaps of the categories. The relevance of the subcategories was justified with reference to the theoretical literature (e.g., Erduran & Dagher, 2014a; Irzik & Nola, 2011, 2014) and through discussion by all three coders.

After forming reasonable subcategories, the second author was trained in the established coding procedure with consideration of the coding guidelines, including the category system. The second author then coded 15% of the selected four chapters of all seven textbooks (Kuckartz & Rädiker, 2019; Syed & Nelson, 2015). The selection of the 15% was performed randomly with the use of the R software (R Core Team, 2019). During the coding process performed by the second author of this study, the category system was refined again by inductively adding further subcategories in line with the theoretical framework. Also, subcategories which caused need for clarification were repeatedly discussed with experts of biology education researchers ($N = 8$). For the clarification of a few subcategories a molecular biologist was additionally consulted.

To systematically determine the reliability of the category system, 15% of the material was coded again by the same second author after 2 weeks (Krüger & Riemeier, 2014). Cohens' Kappa (κ) was calculated as a measure of intrarater-reliability and is regarded as "almost perfect" ($\kappa = 0.95$; Landis & Koch, 1977; p. 165). Subsequently, a student assistant was trained for coding by use of the coding guideline, the category system, and several test coding procedures including supporting discussions with the authors. The independent second coding by the student assistant of 15% of the material revealed a "substantial" interrater-reliability ($\kappa = 0.80$; Landis & Koch, 1977; p. 165).

5 | RESULTS

The initial category system based on the FRA included four categories for the cognitive-epistemic system and seven categories for the social-institutional system of science (Table 1; Erduran & Dagher, 2014a), all of which have been found in the randomly selected 15% of the four chapters in the seven textbooks, albeit some with only a small amount of codings (e.g., category [9] "Social Organizations and Interactions," $n_{codings}$ = 10). As a result of discussing the overlaps, the category system was modified by splitting the category "methods and methodological rules" (Table 1) into two separate categories. Also, "social certification and dissemination" (Table 1) was merged into (7) "professional activities." Both decisions will be justified below. Thus, the cognitive-epistemic system now consists of five main categories; the social-institutional system contains six main categories. The 11 categories were differentiated into 52 subcategories (Table 2).

In the following, the scope of the identified categories will be shortly described. For the development of the category system, the theoretical work of Irzik and Nola (2011, 2014), as well as Erduran and Dagher (2014a), was largely used. Additional sources that were used are cited where appropriate.

5.1 | Categories of the cognitive-epistemic system of science

Category (1) "Cognitive-epistemic aims and values" includes seven subcategories such as (1a) "objectivity" and (1b) "Testability" (Table 2).

Category (2) "Scientific practices" is differentiated into three parts: The subcategories (2a) to (2d) refer to specific practices such as observing and experimenting, which are highlighted as styles of investigation (in German "Erkenntnismethoden") in the corresponding official curriculum (e.g., KMK, 2020) and in educational literature focusing on biology education in Germany (e.g., Wellnitz & Mayer, 2013). The subcategories (2e) to (2g) include specific work techniques, which are used by scientists to support these practices on a practical level (Meier & Mayer, 2014). Subcategories (2h) to (2k) refer to different forms of documentation, which aim to record procedure steps or research findings (Table 2).

Category (3) "Methods" is differentiated into two parts: "Scientific approaches" and "Forms of Reasoning." The first includes scientific approaches involving systematic courses of action following several steps (e.g., asking questions, constructing hypotheses; Irzik & Nola, 2011). The subcategory (3a) "Hypothetical-deductive approach" can be understood as such a systematic course of action, outlined in the example given in Table 2. Considering that different scientific approaches pursue different targets (e.g., testing a hypothesis, deriving a hypothesis; Erduran & Dagher, 2014a), they can be described by their underlying forms of scientific reasoning (e.g., deductive reasoning, inductive reasoning). Irzik and Nola (2011) identify that "for many […] philosophers, deductive, inductive and abductive reasoning form an important part of any kind of scientific method" (p. 599), and note that the three identified forms of scientific reasoning were listed separately from "Scientific approaches" within the section "Forms of reasoning."

Category (4) "Methodological rules" (Table 2) outlines concrete procedural considerations during the application of (2) "Scientific practices," for example by the (4b) "Conduction of controls" while (2b) "Experimenting." Also, there are content relations to (1) "Cognitive-epistemic aims and values" (as they guide scientific practices), (3) "Reasoning" procedures, and the representation of scientific (5) "Knowledge." Exemplarily, the following text passage provides evidence for the overlap between the categories (3) and (4): "Task: Evaluate the results and explain whether the assumption that the modern human developed by gradual change of regional populations is confirmed or rejected!" (K-SI, p. 331). In this task, the possible rejection of an assumption (as a theoretical construct) is explicitly requested (4a) by data-based evaluation of the assumption, which implicitly represents an abductive procedure (3d). The identified overlaps between (4) "Methodological rules" and other categories justify an

TABLE 2 The 11 categories of the family resemblance approach (FRA), its subcategories, and evidence found from the analysis of seven biology school textbooks

Code	Subcategory	Description	Evidence from the textbook
1	**Cognitive-epistemic aims and values**	Scientific research is guided by cognitive-epistemic aims and values concerning…	
1a	Objectivity	… objectivity: It is named or described that science aims to gain objectively achieved knowledge.	Science enhances knowledge by gaining objective data, […] (C-SII, p. 14)
1b	Testability	… testability: It is named or described that research questions and scientific statements must be testable and, when required, falsifiable/verifiable (e.g., in the case of hypotheses).	From the fact that science is concerned with testable statements, it does not follow that there are only scientifically testable matters in the world. (W-SII-L, p. 551)
1c	Novelty	… novelty: It is named or described that science is searching for new explanations.	Until the middle of the 19th century, it was not known how characteristics are inherited. Only through many experiments by the monk Mendel were the so far unknown regularities of heredity successfully proven. (C-SI, p. 256)
1d	Criticism	… alternative ideas: It is named or described that science can lead to opposite ideas or that science seeks and values criticism or responds to objections.	It is understandable that the spectacular fossil finding led to severe disputes between proponents and opponents of the evolutionary theory very soon after its discovery. (C-SII, p. 274)
1e	Empirical adequacy	… empirical adequacy: It is named or described that science is basing claims on sufficient, relevant, and plausible data.	At least 1 s big wave of emigration, which is dated in the time period of 800,000 to 1 million years ago, has been confirmed: populations arrived in Asia but also in Europe. (C-SII, p. 286)
2	**Scientific practices**		
	Practices	Natural objects, processes, and systems are …	
2a	Observing	… observed: Characteristics of direct or indirect observations are named. Observations also include fossil finds. Observations conducted by scientists are named or described; students are asked to observe or to reflect on the practice of observing.	Observation is grasping objects or processes with the senses without influencing them. The use of observation aids such as the microscope does not change the principle of the method: each observation is filtered and limited by the performance of the senses or the instruments. (C-SII, p. 14)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
2b	Experimenting	… investigated experimentally: Characteristics of experiments are named, for example, in an experiment, one intervenes in the function of an object, a process, or a system; experiments and investigations with experimental characteristics conducted by scientists are named or described; students are asked to experiment or to reflect on the practice of experimenting.	Scientific experiment. Also in a scientific experiment, data are generated, interpreted, and discussed with the purpose of finding answers to a research question. In contrast to an observation, in an experiment one intervenes in the function of a biological system, for instance by pressing blood vessels to stop blood flow. (W-SII-L, p. 15)
2c	Comparing and classifying	… compared and classified: Characteristics of the methods comparison and/or classification are named; comparisons and/or classifications conducted by scientists are named or described; students are asked to compare and/or classify or to reflect on the practice of comparing and/or classifying.	Classification in the natural system. If you want to classify a living being in the natural system, you have to analyze its similarity to other living things and find homologies as the cause of the similarity. […] (C-SII, p. 268)
2d	Modeling	… investigated by use of models/model organisms: Characteristics of the modeling process with or without using model organisms are named, for example, by modeling one can represent an idea of the investigated object structure; modeling processes conducted by scientists are named or described; students are asked to model or to reflect on the practice of modeling.	They used data and findings from other scientists such as Rosalind Franklin (1920–1958) and derived the spatial structure of DNA with a model. (K-SII, p. 146)
	Work techniques	Natural objects, processes, and systems are observed, experimentally investigated, compared and classified, or investigated with the use of models/model organisms with the aid of …	
2e	Chemical and physical techniques	… chemical and physical techniques: Characteristics or the significance of the functional use of tools in chemical and physical techniques are named or described, for example, using the microscope, the application of chemicals, physical measuring instruments, cultivating and culturing cells, gene transfer, DNA-chip-technologies, polymerase chain reaction; students are asked to conduct or reflect chemical and physical techniques.	Recombinant DNA can be converted into gene products only if it gets into the host cell. Commonly, vectors with specific characteristics are used for the transmission. Vectors must be replicable, which means they have a sequence that functions as the origin of the replication. […] (C-SII, p. 188)

(Continues)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
2f	Mathematization	… mathematization: Characteristics or the significance of the functional use of tools in mathematical techniques are named or described, for example, formalization, quantification; students are asked to conduct or reflect techniques of mathematization.	He investigated more than 10,000 plants and incorporated the findings completely into the study, which means he assessed them statistically. Such an approach was strange for biologists in his time. (C-SII, p. 164)
2g	Preparation	… providing research objects: Characteristics of the functional application of techniques with the aim of preparing examination material are named, for example, procedures concerning excavation works; students are asked to extract research objects.	Many of the work steps are not taking place at the excavation site but in the laboratory. Here, findings have to be cleaned and extracted from remaining rocks. (K-SI, p. 130)
	Documentation	Results or methodical steps are documented by …	
2h	Protocolling	… texts and tables: Protocolling as a form of documentation is named or described; students are asked to prepare a protocol.	"I collected 46 pieces from 39 species on Tuesday; 37 pieces from 33 species on Wednesday, of which 27 were different from the ones of the previous day…" wrote Henry W. Bates in his diary in 1848. (C-SII, p. 238)
2i	Drawing	… sketches and drawings: Drawing as a form of documentation is named or described; students are asked to make a drawing.	Hooke captured all his observations in the form of drawings and sketches. (C-SII, p. 19)
2j	Taking photographs	… photographs: Taking photographs as a form of documentation is named or described; students are asked to take a photograph.	If possible, take a photo of your preparation and produce a karyogram by using it. (C-SII, p. 28)
2k	Constructing diagrams	… diagrams, for example, crossbreed schemata or genealogy trees: Constructing diagrams as a form of documentation is named or described; students are asked to construct a diagram.	The results of the sequencing process can get presented in a "genealogical tree of cytochrome c." Here, the lengths of the lines between two species are communicating how similar the sequences of amino acids of the two species are—the shorter the distance, the more similar the sequences. (W-SII-L, p. 526)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
3	**Methods**	Scientific pathways of acquiring knowledge entail different scientific approaches including distinct lines of thinking implemented in forms of scientific reasoning. Knowledge is gained…	
	Scientific approaches		
3a	Hypothetical-deductive approach	… by the hypothetical-deductive approach: It is named or described that scientific inquiry is guided by a procedure, which goes from a research question over to generating a deductive hypothesis culminating in the conduction of a certain practice revealing data, which are analyzed and discussed in the aim of falsifying or supporting the initial hypothesis.	Figure including the following steps: Research question ➡ Generating a hypothesis ➡ Planning an experiment to verify the hypothesis ➡ Conducting the experiment ➡ Describing the data ➡ Discussion: Was the hypothesis falsified or supported? (W-SII-L, figure 14.2 "Acquiring knowledge by experimenting," p. 14)
	Forms of reasoning		
3b	Inductive reasoning	… inductively: It is named or described that general knowledge is obtained from the abstraction of single findings; students are asked to reason inductively.	From the observation of cell divisions, (Rudolf Virchow) concluded that all cells arise only from existing cells: Omnis cellula e cellula. (C-SII, p. 19)
3c	Deductive reasoning	… deductively: It is named or described that single findings are predicted by considering well-known cases and hence, general knowledge; students are asked to reason deductively.	*Task*: Explain which consequences would emerge if the reduction division during the production of gametes would not take place. (C-II, p. 267)
3d	Abductive reasoning	… abductively: It is named or described that reasons for an observation are given by considering prior knowledge and hence, inferring a coherent causal conclusion on the certain case; students are asked to reason abductively.	Mendel already assumed that self-pollination and autogamy, processes that are common for pea plants, cause the level of homozygosity. (C-SII, p. 164)
4	**Methodological rules**	In scientific practices, scientists follow the methodological rules, so that …	
4a	Rejection or change of theoretical constructs	… theoretical constructs are rejected or changed: It is named or described that scientific constructs such as hypotheses, theories, or models are being rejected or changed, for example, because of new findings.	Therefore, it is understandable that statements about the course of the phylogeny contain some uncertainty and must be repeatedly modified or even revised due to new findings. (C-SII, p. 290)
4b	Conduction of controls	… controls are conducted: It is named or described that, when applying one of the scientific practices (e.g., observing, experimenting), controls	*Task*: […] Repeat the process for each catalase concentration at least three times. (K-SII, p. 69)

(Continues)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
		need to be considered, for example, repetitions or control groups.	
4c	Choice of sample size	… an appropriate sample size is chosen: It is named or described that, considering statistical analyses, scientific research needs to be based on a big sample size.	*Task*: Justify why a large number of individuals had to be counted to secure the results. (C-SI, p. 261) *Answer*: In statistical measurements, the more single results you have, the more exact your final result will be. (C-SI solutions, p. 104)
4d	Choice of research object	… an appropriate research object is chosen: It is named or described that, considering a specific research question, the research object must show relevant characteristics (e.g., durability, variability) or fulfill corresponding criteria (e.g., expenses).	Osmosis and plasmolysis are investigated well on plant tissue, because it has stable cell walls. (C-SII, p. 50)
4e	Avoidance of ad-hoc changes in theoretical constructs	… ad hoc changes in theoretical constructs are avoided: It is named or described that, considering the explanatory potential of theoretical constructs, they must not be changed because of new evidence if it is still justified by other evidence.	Despite all difficulties in individual cases (regarding the ambiguity of findings), the fundamentals of human fossil history are uncontroversial. (C-SII, p. 290)
5	**Scientific knowledge**	Scientific knowledge as a product of the scientific enterprise highlighting their contribution to their growth is represented in …	
5a	Hypotheses	… hypotheses: The term "hypothesis" is defined, functions and characteristics of hypotheses are named.	A scientific hypothesis is a justified assumption, which stands in line with scientific knowledge and represents a possible answer for a research question. A hypothesis must be formulated without internal contradictions and must be testable. (W-SII-L, p. 14-15)
5b	Theories	… theories: The term "theory" is defined; functions and characteristics of theories are named.	Even a theory—a system of scientifically justified, self-consistent statements for the description, explanation, and prediction of reality—always remains preliminary knowledge. No theory can be "proved" by new findings, but only supported, questioned, or refuted. (C-SII, p. 14)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
5c	Models	… models: The term "model" is defined; functions and characteristics of models are named.	Every scientific model represents an approximation to reality. It attempts to explain as many observations and known facts as possible. It also allows for predictions that guide further research. New findings often make it necessary to develop a valid model or even replace it with a new one. (C-SII, p. 46)
5d	Rules	… rules: The term "rule" is defined; functions and characteristics of rules are named.	Particularities of biology. For a long time, biology was deemed to be "imperfect physics." Biological findings are less universal, rarely able to be formulated as "laws" and can hardly be mathematically described." (C-SII, p. 15)
6	**Professional activities**	In addition to the design, performance, and evaluation of scientific studies, scientists also …	
6a	Publishing findings	… publish findings: It is named or described that research findings are published, for example, in research articles, textbooks, or via the internet.	In 1865, he first presented his findings verbally at Naturforschender Verein Brünn (Association of Natural Sciences Brünn) and then published them 1 year later. (C-SI, p. 257)
6b	Evaluating research quality	… evaluate the quality of research: It is named or described that research methods or findings are evaluated socially, so that they are legitimated, criticized, or misjudged by other scientists, for example, in a peer review process.	The criticism of peers soon led Haeckel to admit that he had adapted the published drawings idealizing his ideas of evolution. (C-SII, p. 264)
6c	Undertaking research trips	… undertake research trips: It is named or described that scientists travel to carry out their research work, for example, by a trip to another country.	As a 22-year-old student, Darwin had the opportunity to take part on a research trip aboard the survey ship "Beagle." On this trip, which lasted from 1831 to 1836, he collected many animals and plants. (C-SI, p. 310)
6d	Receiving awards and prizes	… receive awards and prizes: It is named or described that scientists are supported, appreciated, or honored with material or nonmaterial goods so that they achieve acclaim, for example, by receiving the Nobel Prize.	The photograph shows the scientists James Watson (left) and Francis Crick (right), who developed in 1953 a structure model of the molecule that genetic material is made of: the DNA. In 1962, they received the Nobel Prize for medicine. (C-SII, p. 132)

(Continues)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
7	**Scientific ethos**	Guided by ethical values, scientific research processes are considered to ...	
7a	Respect of Research objects	... respect research subjects: Characteristics of the protection of research subjects as a value are named, for example, avoiding injuries and reducing harm that could occur in the conduction of an experiment.	The amount of animal studies could have been reduced with the help of cell cultures. (K-SII, p. 32)
7b	Respect for the environment	... respect the environment: Characteristics of environmental protection as a value are named, for example, considering conditions that endanger nature and environment.	The ecological risks are seen mostly in the distribution of transgenic plants and their possible effects on herbivores. (C-SII, p. 194)
7c	Protection of human subjects	... protect human subjects from consequences of research: Characteristics of the protection of humans from unethical research as a value are named, for example, considering conditions that endanger human dignity.	Critics warn of possible transition of antibiotic resistance genes on other bacteria, and also on human pathogens. (C-SII, p. 189)
7d	Confidentiality	... mind the protection of personal data and privacy: Characteristics of confidentiality as a value is named, for example, individual data may need to be kept confidential.	Critics also fear that genetic data could be collected without the consent of those affected and passed on to third parties without authorization. (C-SII, p. 193)
7e	Communalism	... be made transparent and accessible to other scientific disciplines so that scientific methods and techniques used for a certain research issue as well as their findings are used by other scientists: Characteristics of transparency and accessibility as values are named, for example, scientific knowledge is commonly shared, and scientists are open toward discussion.	In his book about the pollination of orchids via insects, which was first published in 1862, Darwin investigated both British and foreign species of the orchid that had been sent to him by other scientists. (C-SII, p. 248)
7 f	Legality	... be held within the borders of legality: Characteristics of obedience to law and regulations as a value are named, for example, scientists accept the limits of legal frameworks and obey regulations.	Although therapeutic cloning is regarded as morally right from a utilitarian perspective, it is prohibited in Germany. Anyone who goes with this ethical justification must still adhere to the law. (W-SII-L, p. 230)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
8	**Social utility**	Scientific research supports …	
8a	Improving human health	… human health: It is named or described, that scientific research and its findings support human health, for example, to raise life expectancy, to enable better diagnosis and treatment of medical diseases.	Through the advances in medical treatments, the life expectancy of people with trisomy 21 has considerably improved over the last decades. (C-SI, p. 284)
8b	Supporting nature conservation	… nature conservation: It is named or described that scientific research and its findings support environment protection, for example, by investigating certain research objects.	The fish has been developed as a living test system for environmental monitoring. By linking the fluorescence genes with a biological sensor, the animals should monitor the occurrence of harmful substances. (C-SII, p. 196)
8c	Serving justice	… justice: It is named or described that scientific research and its findings support justice, for example, by the conduction of police investigations.	Furthermore, DNA analysis enables identification of those suspected of perpetrating crimes. (C-SII, p. 140)
9	**Social organization and interactions**	Scientists work in social forms that are determined …	
9a	Teamwork	… by the scientists themselves: It is named or described that scientists work together in a team.	In 2012, the French microbiologist Emmanuelle Charpentier and her American colleague Jennifer Doudna described a new "tool" for genetic engineering. (W-SII-L, p. 181)
9b	Social organization of institutions	… by institutions: It is named or described that an institutional organization arranges and coordinates the social form in which scientists work together.	From 1990, under the coordination of the International Human Genome Organization (HUGO), more than 1000 scientists in many countries worked to fully decipher the human genome. (C-SII, p. 193)
10	**Power structures**	Scientific activities are regimented and controlled by power structures originated in …	
10a	Scientific community	… the scientific community itself: It is named or described that the scientific progress is driven by scientists who are in competition with each other, for example, by scientists coming under pressure to publish their results quickly.	However, Darwin did not publish it until 1859, when he came under pressure through a manuscript by the naturalist Alfred Wallace (1823–1913) about the theory of natural selection. (W-SII-L, 2014, p. 426)
10b	Science and policy	… policy: It is named or described that political, national, and international organizations and legislatures have an influence on scientific activities,	Preimplantation diagnosis (PID) is prohibited in Germany, while in other countries it is legal. However, PID is not illegal in Germany if

(Continues)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
		for example, by providing guidelines and laws for science and its research and applications.	there is a risk of heavy hereditary diseases (status as of 2015). (W-SI, p. 328)
10c	Science and religion	… religion: It is named or described that religious conceptions and convictions have an influence on scientific activities, for example, by putting religious beliefs on an equal footing with scientific findings, which undermines the cognitive-epistemic aims and values of science.	Creationist beliefs are significant especially to Christian fundamentalist and Evangelical communities in the United States and are widely getting disseminated. The adherents criticize not only the theory of the origin of species, but more generally godlessness and science. (W-SII-L, p. 551)
10d	Science and society	… society: It is named or described that social dynamics in society have an influence on scientific activities and vice versa, for example, when public pressure leads to an alignment of research purposes following the needs, desires, and requests coming from civil society.	The desire for a healthy child in conjunction with advances in gene analyses has led to pre-implantation diagnosis […]. (W-SI, p. 328)
10e	Interplay of science with "race"	… the interplay of science with "race": Historical accounts on the view of science on the concept of 'race' or regarding gender are given, or the influence of scientific findings on the concept of "race" is named or described.	[…] many of [Darwin's] statements were transferred to human society and hence, were used to form social Darwinism. They alleged that cultural and social transformations were subjected to natural selection. Thus, races were not only differentiated but also rated. In this matter one's own race was seen as superior or of higher value. (C-SI, p. 332)
11	**Economics of science**	Scientific practices and findings are used and/or regimented by economics …	
11a	Application and transmission	… in the aim of application and transmission: It is named or described that industrial products and processes are improved by science via application of scientific methods or transmission of scientific findings to the industry (e.g., in bionics).	As substitutes for plastics, raw materials from various plant species are eligible, such as starch from potatoes or corn. Methods have been developed to produce cups and plates from starch by baking or injection molding. (C-SII, p. 63) Some technical innovations take advantage of models from nature, for example, the shell of airplanes and ships which is designed based on the model of sharkskin. (C-SI, p. 334)

TABLE 2 (Continued)

Code	Subcategory	Description	Evidence from the textbook
11b	Commodification and commercialization	… in the aim of commodification and commercialization: It is named or described that products and processes, which are taken from science, are introduced to the market for higher yields.	Flavors, vitamins, flavor enhancers, […] are typical food additives. Genetically modified organisms should produce these substances more […] cheaply. (C-SII, p. 195)
11c	Financial support	… by financial support: It is named or described that scientific research is supported financially, for example, by research funding organizations.	Additionally, for commercial reasons the verification of relatively widespread mutations is of primary importance. (C-SII, p. 197)

Note: The abbreviations of the textbook sources (e.g., C-SII) are outlined under "sample"; the original statements made in the textbooks were in German and may differ slightly from their original syntax.

autonomous category opposed to methods and methodological rules as one category in the original FRA (Table 1; Erduran & Dagher, 2014a; Irzik & Nola, 2011, 2014).

The subcategories (5a) "Hypotheses," (5b) "Theories," and (5c) "Models" were identified as specific forms of (5) "Knowledge" (Table 2). Category (5c) "Models" also includes the use and significance of model organisms, as identified within the following: "The most important findings of molecular biology were gained from bacteria and viruses. These simple biological systems are particularly suitable as model organisms/models on which fundamental molecular mechanisms can be well investigated" (C-SII, p. 142). Instead of laws (Erduran & Dagher, 2014a; Table 1), the subcategory (5d) "Rules" aligns much better to the data and the restriction formulated by Irzik and Nola (2011) that "not all sciences may have laws" (p. 600; see Rosenberg, 2008). Correspondingly, data showed that there are 18 codings including the term "rule" and 10 codings including the term "law." Several overlaps of codings were identified between the categories (5) "Knowledge" and (2) "Scientific practices." This can be mainly explained by descriptions of the testing and validation of the different knowledge forms. Evidence provides the following example, which was coded in the subcategories (5a) "Hypotheses" and (2b) "Experimenting":

Experiments are designed and conducted in such a way that the hypothesis can be examined with it. If the results are in accordance with the hypothesis, it is more likely to be valid. If they contradict, another hypothesis must be proposed and examined (K-SI, p. 7)

5.2 | Categories of the social-institutional system of science

The results regarding the categories of the social-institutional system of science show that there are overlaps between the initial FRA categories of professional activities and social certification and dissemination (Table 1; Erduran & Dagher, 2014a). Exemplarily, the following textbook example provides evidence: "In 1865, [Johann Gregor Mendel] first presented his findings verbally at Naturforschender Verein Brünn [Association of Natural Sciences Brünn] and then published them 1 year later" (C-SI, p. 257). As the verbal presentation and the publication of research findings are identified both as professional activities and activities regarding the social certification and dissemination, the two initial FRA categories were merged into (6) "Professional activities" containing, among others, the subcategories (6a) "Publishing findings" and (6b) "Evaluating research quality" (Table 2).

Most of the coded text passages regarding the social values of science (Table 1; Erduran & Dagher, 2014a) were shifted to (7) "Scientific ethos," which consists of six subcategories (Table 2). Following Resnik (2007), ethical principles such as respecting research objects and obeying the law are listed as opposed to epistemological norms for scientific research, which are contained in (1) "Cognitive-epistemic aims and values." Other text passages regarding social values were identified and included the improvement of human health, the support to conserve nature, and the service for justice as applications of scientific research in social contexts. Thus, the initial FRA category of social values of science (Table 1; Erduran & Dagher, 2014a) was renamed into (8) "Social utility" containing three subcategories (Table 2).

Category (9) "Social organizations and interactions" differentiates two subcategories by concerning the level of contribution made by scientific institutions (Table 2). Elements which focus on teamwork as social form (9a) are differentiated from those which outline the impact of institutional organization on the interaction of scientists (9b).

It was found that not only content about political power structures is included in the textbooks (Table 1; Erduran & Dagher, 2014a) but also content about power structures within the scientific community itself (10a) and in other domains of life that have an impact on scientific research (e.g., [10c] "Science and religion"; Table 2).

The category (11) "Economics of science" consists of three subcategories, differentiating the application and transmission (11a) and the commodification and commercialization (11b) of science in the industry (Table 2; Kaya, Erduran, Birdthirstle, & McCormack, 2018) on the one hand, and financial support (11c) of scientific research on the other hand.

6 | DISCUSSION

6.1 | FRA categories within the potentially implemented biology curriculum (RQ 1)

The analysis of four chapters from seven biology textbooks as potentially implemented biology curriculum (Remillard & Heck, 2014) revealed five categories for the cognitive-epistemic system of science with 29 subcategories, and six categories for the social-institutional system of science with 23 subcategories (Table 2). Consequently, the analyzed textbooks contain potential of learning about NOS content that is represented within the curriculum. Additionally, it indicates that the FRA (Erduran & Dagher, 2014a) can be considered a fruitful approach for identifying of NOS content in biology school textbooks, which is in line with other textbook studies based on the FRA (e.g., McDonald, 2017; Park et al., 2019). For example, using the FRA allowed the empirical identification of the significance of models shown in Table 2 ([5c] "Models"). Regarding possible discipline-specificities, the identification of the role and function of model organisms in biological research (see above) supports the advantage of the FRA as a useful tool for the identification of biology-specific NOS aspects. Conversely, scientific models are not explicitly included in discipline-general NOS conceptualizations such as the consensus view (Lederman & Lederman, 2014). Thus, corresponding textbook elements would not be detected when using the latter approach. A further example relates to the significance of laws: Within the discipline-general NOS conceptualization, "laws" are mostly derived from the field of physics (Dogan & Abd-el-Khalick, 2008; Schizas et al., 2016). However, it is questioned if anything that could be called a law even exists in biology (Reutlinger et al., 2019; Rosenberg, 2008). Through use of the FRA, this issue could have been empirically identified in the textbooks as shown in the example provided in Table 2 ([5d] "Rules").

It must be noted that, as the FRA is intended to be extendable (Erduran & Dagher, 2014a), further analysis of textbook material (especially from other school science subjects) might lead to the construction of additional NOS categories. It can be strongly assumed that an analysis of other text documents such as philosophical literature would lead to an extension of the category system as well. However, we want to remark that the relevance of such related future findings for different school levels would need to be evaluated along further analyses considering primarily science education and using science philosophy as a theoretical and not educational background.

Some of the FRA categories in other studies were found to possess limited content. Park et al. (2019) discovered content referring to science as a social-institutional system to be underrepresented in the physics textbooks they analyzed. For three categories, they did not find evidence at all. In contrast, the present study revealed at least two distinct NOS aspects (i.e., subcategories) for each FRA category. In the present study, textbooks from Germany were analyzed, while in the other studies textbooks from Lebanon (BouJaoude et al., 2017), Australia (McDonald, 2017), and Korea (Park et al., 2019) were analyzed. It might be generative to analyze and compare underlying official curriculum within various country as the design of NOS content in the potentially implemented curricula follows potential learning experiences and goals formulated in the intended curricula of the respective country (e.g., standards documents; Remillard & Heck, 2014). It can be assumed that the identified NOS content stands in accordance with them (Park et al., 2019). Several studies on NOS analyzing such official documents (e.g., Erduran & Dagher, 2014b; Kaya & Erduran, 2016) demonstrate the usability of the FRA for these research purposes. By investigating the relationship between NOS representations in standards and textbooks, fruitful implementations could be made as to which (intended) curricular requirements are necessary to implement NOS content in school textbooks and ultimately in science classes.

While BouJaoude et al. (2017) analyzed textbooks for ninth grade and McDonald (2017) analyzed junior secondary textbooks for Grades 7–10, in this study, textbooks for higher secondary levels (Grades 11–13) were analyzed as well. Thus, we assume that material for higher secondary levels includes a broader coverage of different NOS aspects. However, Park et al. (2019) also analyzed high school textbooks for Grades 11 and 12 and found that social-institutional NOS content is underrepresented. This partly contradicts the findings of this study which revealed at least two subcategories for each of the categories of the social-institutional system. One explanation for this can be the different disciplines of the textbooks analyzed in Park et al. (2019; physics) and in this study (biology). However, further research is needed here.

A comparison of this study with the one made by McDonald (2017) shows that the analysis of different topics of biology (cell biology, genetics, and evolutionary biology) provides more NOS content than the data relying only on one topic such as genetics (McDonald, 2017). Typically, an introductory chapter such as a general method section also contains more NOS aspects than chapters that focus on certain subject-related contents (Abd-El-Khalick et al., 2008, 2017; Chiappetta & Fillman, 2007). McDonald (2017) states that the FRA is a useful tool to detect NOS aspects without the need of all of them being included in all contexts. She supports the conduction of further textbook studies based on the FRA concerning other conceptual domains such as evolution, which she suggests might lead to new perspectives on relevant NOS aspects (McDonald, 2017). Our findings support this suggestion. However, it is still questionable which NOS aspects are represented in certain textbook chapters (i.e., certain subdisciplines of biology). It can be assumed that by considering material which aligns to different subdisciplines of biology, a more diverse view on NOS content will be presented than if one just focused on one subdiscipline. Furthermore, a systematic study focusing on analyzing possible correlations between FRA (sub) categories and certain textbook chapters might give hints as to which biology-related topics can be used in the classroom to foster certain NOS aspects (Erduran et al., 2019). For example, Kampourakis (2016) considered such NOS content to be "discipline-specific aspects, which are unique to specific disciplines (e.g., paleontology has a historical dimension that molecular biology lacks)" (p. 678). He suggests using such content at the end of a learning pathway in which general NOS aspects are implemented first while discipline-specific aspects are used ultimately to highlight "specific characteristics of each discipline as well as the differences among them" (p. 678). The present study gives hints that such an approach could be available as school textbooks seem to offer general as well as (sub) discipline-specific NOS content.

Connecting to Kampourakis' (2016) suggestions of a learning pathway, we propose that the current category system (Table 2) includes both discipline-general and biology-specific NOS content which should be investigated further: (i) Discipline-general NOS content refers to subcategories, which relate to all or most disciplines of the natural sciences (e.g., [1a] "Objectivity", Table 2; Resnik, 2007). (ii) Discipline-general NOS content with inherent specifications for biology refers to subcategories, whose content partly relates specifically to biology such as model organisms as one form of models. Furthermore, in search of errors in biological experiments, the variability of living creatures as research objects must be considered (Bässler, 1991; [2b] "Experimenting," Table 2). (iii) Biology-specific NOS content refers to subcategories, which relate only to biology or very close-related subdisciplines such as biochemistry (e.g., [7a] "Respect for research objects," Table 2; Resnik, 2007). This three-way division should not be considered a static categorization of NOS content, but rather a dynamic one. Therefore, the concept of a continuum used by Kampourakis (2016) should be subscribed to which will allow NOS content to be classified along this continuum.

The diversity of the subcategories in the present analysis resulted from the fact that not only explicit, but also implicit NOS content (e.g., Abd-El-Khalick et al., 2008, 2017) was considered within the analysis. Although this study does not provide a systematic survey on this topic, there is a perceived high rate of implicit representations. For example, implicit text passages in the category (1) "Cognitive-epistemic aims and values" (Table 2) might be explained by the unfamiliarity of aims and values within the science education literature in general (Erduran & Dagher, 2016). Implicit represented NOS content in school textbooks contributes less to fostering an adequate NOS understanding of students compared to explicit representations (Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Lederman & Lederman, 2014; see Abd-El-Khalick et al., 2008, 2017). However, such implicit representations still subtly provide starting points to explicitly address the related NOS content in science education. For this, teachers need to recognize and capitalize upon implicitly represented opportunities for NOS learning.

Implicit NOS representations can also be used for deriving concrete remarks on the adequacy of NOS contents in school textbooks. The following statement from a chapter of evolution gives an example: "Fossil findings give evidence that the evolution of humans began in Africa. […]" (K-SI, p. 146; [1e] "Empirical adequacy," Table 2). Whereas this quote and the following sentences are mainly concerned with biological content knowledge about the evolution of humans, characteristics of terms such as verification, confirmation, falsification, and so on. in the process of gaining and evaluating knowledge are not addressed. As a result, empirical adequacy as a cognitive-epistemic aim and value determining scientific research is not explicitly presented. Characterizing relevant terms and outlining the way of gaining and confirming new knowledge by prompts, questions, or remarks would enable teachers to foster an adequate NOS understanding with the use of a textbook (McDonald, 2017; Park et al., 2019).

More generally, text passages and other textbook elements that explicitly provide NOS content would be a fruitful starting point to foster students' NOS comprehension. Erduran and Dagher (2014a) extend this by demanding, for example, that "aims and values in science [should] become assessment goals, [otherwise] they will likely be sidelined in classroom instruction" (p. 54). Van Dijk (2011) argues that a "clear understanding of the roles of values in science enables us to decide whether their role is acceptable, which can be assumed to be an important element of functional scientific literacy" (p. 1097). To support the fostering of such an understanding, interventions with an explicit NOS focus need to be developed and implemented in science classrooms. Erduran and Dagher (2014a) suggest the construction of several levels of knowledge including, among others, different aims and values in science students can have ("needs improvement", "satisfactory," "target"; p. 55). The category system in this study could be used to extend this approach by using it as a starting point to clarify *what* NOS content students should understand. For this, different levels of school textbooks need to be considered (i.e., lower levels with Grades 5–10 and senior levels with Grades 11–13) as well as the normative standards set for different levels as outlined in the official curriculum (e.g., KMK, 2020).

6.2 | Discriminatory power of the FRA categories (RQ 2)

To evaluate the usability of the FRA (Erduran & Dagher, 2014a) as a category system to describe NOS content in a sufficient and adequate way (Schreier, 2012, 2014; Schreier et al., 2019), the discriminatory power of the initial FRA categories (Table 1) as well as of the identified subcategories (Table 2) were evaluated. Several methodical procedures were conducted, which contribute to the legitimation of the category system. In general, changes of the initial FRA categories (Table 1) and the development of the subcategories were discussed among the involved researchers during the whole process (member checking as part of a communicative validation; Kuckartz, 2018).

The coding procedure itself was done in a successive manner with several discussions of textbook elements, which were difficult to code (consensus coding; Schreier, 2012, 2014).

Multiple meanings of codings were considered during the qualitative content analysis process. On the one hand, meanings can be traced back to content-related overlaps of categories that are identified to have a low discriminatory power. On the other hand, they might refer to the occurrence of more than one NOS aspect in the same coding unit that is represented in a strongly connected way. Theoretically justifiable overlaps were identified, which do not challenge the justification of different subcategories and hence, the adequacy of their description (Spendrin, 2019). One example for that is the above-quoted text passage (K-SI, p. 7) about experiments (2b) and its purpose to test for hypotheses (5a). Such overlaps can be explained by the proximity of the categories regarding their content. As those theoretical overlaps show, the FRA depicts “science as a holistic, dynamic, interactive and comprehensive system subject to various influences” (Erduran & Dagher, 2014a; p. 29). At the same time, the calculated interrater-reliability ($\kappa = 0.80$) shows that despite the occurrence of overlaps the category system can be evaluated as useful and the categories as distinct from one another. The “substantial” (Landis & Koch, 1977; p. 165) agreement between two persons when independently coding the same material with the same coding guideline hints to a reliable usage of the category system (Schreier, 2012).

7 | CONCLUSION AND FUTURE PROSPECTS

The analysis of the textbooks led to a more differentiated category system, including modifications to the main categories provided by Erduran and Dagher (2014a). As a next step, the category system will be applied on further material, as the present analysis has been done only on 15% of the sample. The remaining 85% of the selected four chapters (e.g., genetics) from each of the seven textbooks will be analyzed by use of the category system and the coding guideline. Additionally, by means of a keyword analysis (Kaya & Erduran, 2016), other chapters (e.g., ecology, neurobiology) will be analyzed as well. It is conceivable that analyses of further material (e.g., other chapters) will lead to an extension of the category system by inductively supplementing further subcategories which are theoretically described (e.g., “choosing a theory based on its explanatory power” as a (4) “Methodological rule”; Erduran & Dagher, 2014a; Irzik & Nola, 2011). Following Erduran and Dagher (2014a), “the number of categories can be increased” (p. 143). In line with this, it is conceivable that inductively added subcategories, which are not theoretically described yet within the FRA, will supplement the category system successively.

The FRA is considered to note both discipline-general and discipline-specific NOS characteristics (Erduran & Dagher, 2014a; Irzik & Nola, 2011, 2014). This was not investigated in the present analysis. However, based on the category system (Table 2), we proposed a continuum starting with discipline-general NOS-content and becoming more fine-grained with biology-specific NOS content. We stress the importance of developing and evaluating such a continuum, which includes discipline-specific NOS content. For example, Schizas et al. (2016) highlight the need to differentiate, for example, between the justification of evolutionary theory (as a theory in biology; [5b] “Theories”; Table 2) and theories from the field of physics. Contrary to theories in physics, some students do not accept evolutionary theory, which could be avoided by teaching them the difference between theories in biology and in physics (Schizas et al., 2016). Simply put, biologists often use different practices around collecting solid evidence for a scientific theory (e.g., [2c] “Comparing and classifying”) than physicists do. Such specificities of biology also need to be expressed in school textbooks to raise the acceptance of theories in biology. The identification of discipline-general and biology-specific characteristics can lead to recommendations for school textbooks, but also for (prospective) teachers regarding the design and implementation of biology lessons. The above-outlined continuum requires further research. For this, an expert study could be conducted with a multidisciplinary cohort of philosophers of science and scientists being tasked with deciding if the single subcategories are valid for their own research areas or not. Further studies with textbooks from other school science subjects might present new additions to the category system. A comparison of NOS content in school textbooks of different subjects also might give hints as to which subcategories are primarily relevant for each subject.

Analyzing the adequacy of NOS representations in school textbooks is important for evaluating the appropriateness and thereby the use of textbook material for science education purposes. Applying a rating framework, for example, as outlined in the scoring rubric by Abd-El-Khalick et al. (2008, 2017) would further help to evaluate the way NOS is represented in the analyzed textbooks. This applies especially to the differentiation of identified NOS content into explicit and implicit representations (Abd-El-Khalick et al., 2008, 2017). By applying discipline-specific FRA subcategories to an analysis of the quality of NOS representations, a more detailed understanding of their appropriateness can be derived. On this basis, recommendations for the assessment and future design of biology-related instructional material can be made (Erduran & Dagher, 2014a; Erduran et al., 2019; Kelly & Erduran, 2019).

Furthermore, reflecting different NOS aspects in different contexts and at differing levels of contextualization is effective for introducing NOS instructions and activities (Bell et al., 2016). Regarding the question of *how* NOS can be included in science class it must be noted that NOS teaching approaches are under negotiation in relation to school science traditions. Leden et al. (2020) address the level of contextualization of NOS teaching approaches in the context of school science traditions oriented towards either facts, lab-work, or discussions. The authors report on teachers' view of alignment of decontextualized activities (e.g., black box activities) with the lab-work tradition. Considering the role of lab-work for highlighting primary cognitive-epistemic NOS content, the authors conclude that "an accommodation between NOS and lab-work could mean reducing the NOS content" (p. 23). Decontextualized activities are criticized for addressing general NOS aspects rather than discipline specificities (Schizas et al., 2016). Conversely, contextualized activities (e.g., reflecting on case studies) are well aligned with the discussion tradition and hold the potential to uncover a broad spectrum of NOS (i.e., especially social-institutional NOS aspects), but are more time intensive and are seen as risk-taking by teachers (Leden et al., 2020). However, addressing the social-institutional system of science in an explicit manner through the use of contextualized activities would adequately equip students with the skills and knowledge to deal with socio-scientific issues of science. Appreciating the position of "NOS as a catalyst" (p. 23) in light of a science tradition transformation begs further research to be undertaken on the application of NOS activities in the context of teaching traditions. For this, the occurrence and design of NOS representations in different textbook chapters needs to be examined alongside their level of contextualization as well as a possible orientation toward certain teaching traditions such as the discussion tradition.

In conclusion, a differentiated and evaluated FRA category system for NOS content appears to be a fruitful framework for research purposes in the field of science education, and ultimately it will help foster scientific literacy in science classes as well as in teacher education.

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DATA AVAILABILITY STATEMENT

The school biology textbooks were digitized and analyzed exclusively to answer the scientific research questions. The Copyright and Related Rights Act (Urheberrechtsgesetz) is complied with in accordance with §60d (Text and Data Mining). The textbooks were scanned, converted to PDF files, and stored under lock and key. No more than 15% of the PDF files are published (German Copyright Act, § 60c Scientific Research). The raw data that support the findings of this study are available from the textbook publishers named in the article. The textbooks are freely available on the market as print version.

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ENDNOTE

[1] At the beginning of the project (i.e., master thesis of Weißberg & Roenz, 2017) a previous version of the textbook W-SII-L was used: LINDER Biologie SII. Lehrbuch für die Oberstufe (*LINDER biology for higher secondary level. Textbook for the senior level*; Bayrhuber et al., 2014; ISBN: 978-3-507-11250-6). After textbook W-SII-L (LINDER Biologie SII; Bayrhuber et al., 2019) was published, this more recent textbook was used for the following analysis.

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